Joseph Otterman[1], Robert Atlas[2], Joseph Ardizzone[3], Thomas Brakke[2], Shu-Hsien Chou[2], Juan Carlos Jusem[3], Michael Glantz[4], Jeff Rogers[5], Yogesh Sud[2], Joel Susskind[2], David Starr[2], Joseph Terry[3]

EXTREME WINTER/EARLY-SPRING TEMPERATURE ANOMALIES IN CENTRAL EUROPE

Abstract. Extreme seasonal fluctuations of the surface-air temperature characterize the climate of central Europe, 45-60°N. Temperature difference between warm 1990 and cold 1996 in the January-March period, persisting for more than two weeks at a time, amounted to 18°C for extensive areas. These anomalies in the surface-air temperature stem in the first place from differences in the low level flow from the eastern North-Atlantic: the value of the Index I_{na} of southwesterlies over the eastern North-Atlantic was 8.0 m s^{-1} in February 1990, but only 2.6 m s^{-1} in February 1996. The primary forcing by warm advection to positive anomalies in monthly mean surface temperature produced strong synoptic-scale uplift at the 700 mb level over some regions in Europe. The strong uplift contributed in 1990 to a much larger cloud-cover over central Europe, which reduced heat-loss to space (greenhouse effect). Thus, spring arrived earlier than usual in 1990, but later than usual in 1996.

1. Introduction

The aim of this paper is to report extreme winter/early-spring temperature anomalies in central Europe, and to discuss the underlying forcing to these interannual fluctuations. Warm advection from the North Atlantic in late winter controls the surface-air temperature, as indicated by the substantial correlation between the speed of the surface southwesterlies over the eastern North Atlantic (quantified by a specific Index I_{na}, Otterman, et al., 1999) and the 2-meter level temperature T_s over Europe, 48-54°N; 5-25°E, for January, February and early March. In mid-March and subsequently, the correlation drops drastically (quite often it is negative). This change in the relationship between T_s and I_{na} marks a transition in the control of the surface-air temperature: absorption of insolation replaces the warm advection as the dominant control. The onset of spring defined by this transition occurs on March 16 (Otterman et al., 2000). On the average for the period of that study, the surface-air temperature rises to above 3.5°C on that date. However, the timing for this rise in temperature advances sharply from mid-March when the southwesterlies over the North Atlantic are strong, as we observe in 1990, or can be delayed significantly when the ocean surface winds are not southwesterly, or southwesterly at low speed, as we observe in 1996. The analysis of the ocean-surface winds is based on the Special Sensor Microwave/Imager, SSM/I, dataset. Over land, we use the European Centre Medium-range Weather Forecasts, ECMWF, analysis.

2. SSM/I, ECMWF, TOVS Pathfinder, and GOES-1 NASA/GSFC DAO datasets

From the SSM/I aboard the DMSP satellites, a large dataset of surface wind speeds over the global oceans has been derived. Variational Analysis Method, VAM, was selected to derive

---

[1] Land-Atmosphere-Ocean-Research; at Data Assimilation Office, Code 910.3, NASA/GSFC, Greenbelt, MD 20771
[2] NASA/GSFC, Greenbelt, MD 20771
[3] General Sciences Corporation, Beltsville, MD
[4] NCAR, Boulder, CO
[5] Ohio State University, Columbus, OH

the wind-vector data. In this method, the SSM/I retrievals (that is, the measurements of speed) are combined with independent wind observations to produce consistent fields of wind speed *and* direction. The resulting global ocean-surface dataset is appropriate for climate analysis.

The ECMWF dataset is part of the Basic Level III-A analysis product with the ECMWR/WCRP Global Atmospheric Data Archive. In our study, we use data interpolated horizontally to the standard Goddard Laboratory for Atmospheres grid of 2.0° in latitude and 2.5° in longitude, from the ECMFW archived 2.5° by 2.5° latitude/longitude grid.

The Pathfinder dataset is compiled from measurements in numerous thermal and microwave bands basic to the TIROS Operational Vertical Sounder, TOVS, aboard polar-orbiting NOAA satellites. Temperatures, fluxes, water vapor, and cloudiness at various levels are inferred (Susskind et al., 1997). Monthly anomalies with respect to the 1979-1998 averages have been derived (which we use here for cloud cover analysis).

The Data Assimilation Office, DAO, at Goddard Space Flight Center has produced a multi-year global dataset with version 1 of the Goddard Earth Observing System Data Assimilation System (GEOS-1 DAS; see Schubert et al., 1995). This dataset is suitable for analyzing short-term climate variability. The global output includes all prognostic fields and a large number of diagnostic quantities such as precipitation and surface fluxes.

3. Analysis of ocean-surface winds and vertical motions

The surface winds over the North Atlantic are highly variable, varying in strength, and direction over a period of a few days. Of special interest in climate studies is the interannual variability of monthly and seasonal averages. The value of the Index I_{na} (monthly average of the wind speed at each reporting point in the box 36-50°N, 20-10°W, with contributions only when the direction is southwesterly; when the direction is not from the south-to-west quadrant, the contribution is null; for detailed description of the index see Otterman et al., 1999) was 8.0 m s^{-1} for February 1990. I_{na} was 2.6 m s^{-1} for February 1996. The interannual differences described here persist for several months. In the December 1989-April 1990 period, the winds are extremely strong, characterized by persistent southwesterly "STREAKS," elongated swaths of strong wind at speeds exceeding 15 m s^{-1}, directed toward France and the North Sea. Small regions, "TOPS", where the speed exceeds 24 m s^{-1}, are commonly observed within the "STREAKS". By comparison, in the period December 1995-April 1996, the "STREAKS" appear only on a few occasions; "TOPS" are infrequent. These season-long interannual differences in the ocean-surface winds may be due to a see-saw effect in the Sea Surface Temperature, SST, anomalies. In the eastern extratropical North Atlantic during the period December 1989-April 1990, the SST generally exhibits a positive anomaly in the southeast, but a negative anomaly in the northwest, which creates a tighter SST gradient. This tends to enhance the southwesterlies. On the other hand, the reverse SST situation exists in the period December 1995-April 1996.

The winters of 1989-90 and 1995-96 are well representative of opposite extremes in the strength of the North Atlantic westerlies, as measured by the North Atlantic Oscillation, NAO, index. Sea level pressure gradients across 25°W longitude between latitudes 45-55°N were approximately twice as strong in 1990 as in 1996. Some of the largest sea level pressure differences between the two NAO states typically occur around the Bay of Biscay (Rogers, 1997). During periods such as early 1990, when storms migrate far northeastward of Iceland,

they can advect warm air and cloud cover as far east as central Siberia (Rogers, Mosley-Thompson, 1995).

Only such monthly (or seasonal) data are relevant in climate studies, but insight into the phenomenology of variations can be gained from a single-moment scenario. We illustrate the winter 1990 conditions in Fig. 1, where we note a "STREAK" of southwesterlies directed toward France and England. We observe two "TOPS", one within this "STREAK" and another to the north of Iceland, within a northeasterly "STREAK". Analysis of the streamlines in Fig. 1 suggests that the North Atlantic air masses advected to Europe may originate in the warm southwestern North Atlantic. The low-level warm advection in 1990 produced strong updrafts: ascent rates of up to -0.4 Pa s^{-1} were observed in monthly averages at 700 mb, which were especially strong over the ocean just to the west of Scandinavia. Such high monthly-average ascent rates persisted for four months. By comparison, in 1996 the monthly-average ascent rates at that level were reported generally as zero, with only occasional ±0.1 Pa s^{-1} readings.

How the strong warm advection illustrated in Fig. 1 is affecting the state of the atmosphere is shown in Fig. 2. We observe here at 700 mb large cells of high ascent rates in a 270° "ring" around central Europe. In the strongest cells, one to the northwest of Ireland and the other centered on the southern coast of Scandinavia, the ascent rate tops -1.2 Pa s^{-1}. The monthly-mean February 1990 precipitation exceeded 4.5 mm per day in these locations (GEOS-1 DAS). In cells over Finland, Spain and western Mediterranean, the ascent rates top -0.9 Pa s^{-1}.

4. Analysis of temperatures, relative humidity and cloudiness over the continent

As established in previous studies (Otterman et al., 1999), and analyzed further herein by comparing "warm-Europe" 1990 to "cold-Europe" 1996, warm advection influences strongly the continental surface temperature in Central Europe: the temperature difference between 1990 and 1996 at 2m-height exceeded 18°C for weeks at a time over large areas in the January to March period, see Fig. 3 (from the ECMWF dataset). Only towards the end of March do the differences become small, or vanish entirely. The differences, the positive anomalies in 1990 and negative in 1996, extend over vast regions, deep into the continent. This probably indicates effects of an *in situ* feedback, by increased upper-levels water vapor and clouds that is, by increased greenhouse effect. The elevated surface-air temperature in Feb. 1990 at 60°N, see Fig. 3C and 3D, can be attributed to the extensive anomaly of the cloud fraction, by some 15% (from the Pathfinder dataset).

5. Discussion and Conclusions

The strong maritime-air advection at low level and the associated atmospheric effects on the continent in 1990 produced (i) large positive anomalies in the surface-air temperature, (ii) temperature increases at 850, 500 and 300 mb levels relative to the cold 1996 (by 5°C for February over southern England and France), (iii) significantly higher relative humidity at these levels, (iv) steeper lapse rate (inasmuch as the temperature difference at the surface is much larger than at higher levels), and (v) significantly higher cloud cover over central Europe. [Points (i) to (iv) are from the ECMWF, point (v) is from the TOVS Pathfinder dataset.] In our assessment, the uplifting of the maritime air advected near the surface to higher (and cooler) altitudes observed in winter/early-spring of 1990, by itself and by fomenting high-cloud formation, increases the greenhouse effect. This can be regarded as positive feedback of the

3

primary forcing by low-level transport of maritime-air inland. Analysis of this scenario by General Circulation Models appears worthwhile.

Characterizing climatic conditions for a region involves specifying average values of the key climatic parameters, combined with their variability, that is, the statistics of departures from the averages. Poleward of 35°, the key climate parameter for agriculture and forestry (and for heating-fuel demand) is the surface temperature (both skin and the surface air, which are closely related). Surface temperatures dictate the beginning of planting and seeding at the end of winter, and the harvesting of crops before the next winter sets in. The winter/early spring difference between 1990 and 1996 that we discuss here, persisting at the level of 18°C for more than a week at a time, is extremely large. The source of this assessment, ECMWF analysis, does not offer the accuracy of direct measurements. This reported variability is essentially of the same magnitude that the variation of 14.8°C in the February mean reported for Warsaw (anomaly of 2.6°C in 1957, and −12.2 in 1956; see Table 4.1, p. 78, in Wos', 1999). Such interannual differences in the surface-air temperature exceed the seasonal January-to-April differences (of about 10°C) for Poland (see Fig. 4.2, p. 81, in Wos', 1999). Our suggestion, that the underlying cause is the variability of the surface winds over the North Atlantic, deserves in-depth studies. From observations of phenological events in numerous European stations, Menzel and Fabian (1999) report an advancement of spring by 0.2 days per year in the 30 years of their study since 1960. Menzel and Fabian place this significant climatic trend in the framework of the global warming. In the Balkan stations, however, a decrease in the growing season has been reported, which suggests that alternative or supplemental mechanisms should be examined. Can strengthened low-level southwesterly advection from the ocean in late winter constitute the forcing?

6. References

Atlas, R., R. N. Hoffman, S. C. Bloom, J. C. Jusem, J. Ardizzone, 1996: A multiyear global surface wind velocity dataset using SSM/I wind observations, *Bulletin of the American Meteorol. Soc.*, 77:869-882.

Menzel, A., P. Fabian, 1999: Growing season extended in Europe, *Nature*, 397:65.

Otterman, J., R. Atlas, J. Ardizzone, D. Starr, J. C. Jusem, J. Terry, 1999: Relationship of late-winter temperatures in Europe to North-Atlantic surface winds, *Theoretical and Applied Climatology*, 64:201-211.

Otterman, J., J. Ardizzone, R. Atlas, H. Hu, J. C. Jusem, D. Starr, 2000: Winter-to-spring transition in Europe 48-54°N: from temperature control by advection to control by insolation. *Geophys. Res. Lett.*, 27:561-564.

Rogers, J. C., 1997: North Atlantic storm track variability and its association to the North Atlantic Oscillation and climate variability of Northern Europe. *J. Climate*, 10:1635-1647.

Rogers, J. C., E. Mosley-Thompson, 1995: Atlantic arctic cyclones and the mild Siberian winters of the 1980s, *Geophys. Res. Lett.*, 22:799-802.

Schubert, S., C. Park, C. Wu, W. Higgins, Y. Kondratyeva, A. Molod, L. Takacs, M. Seablom, R. Rood, 1995: Technical Report Series on Global Modeling and Data Assimilation: Volume 6 - A Multiyear Assimilation With the GEOS-1 System: Overview and Results. *NASA Technical Memorandum* 104606, Vol. 6, 207pp.

Susskind, J., P. Piraino, L. Rokke, L. Iredell, A. Mehta, 1997: Characteristics of the TOVS Pathfinder Path A dataset, *Bulletin of the American Meteorol. Soc.*, 7:1449-1472.

Wos', A., 1999: Klimat Polski. (In Polish.) Wydawnictwo Naukowe PWN SA, Warszawa. 302pp.

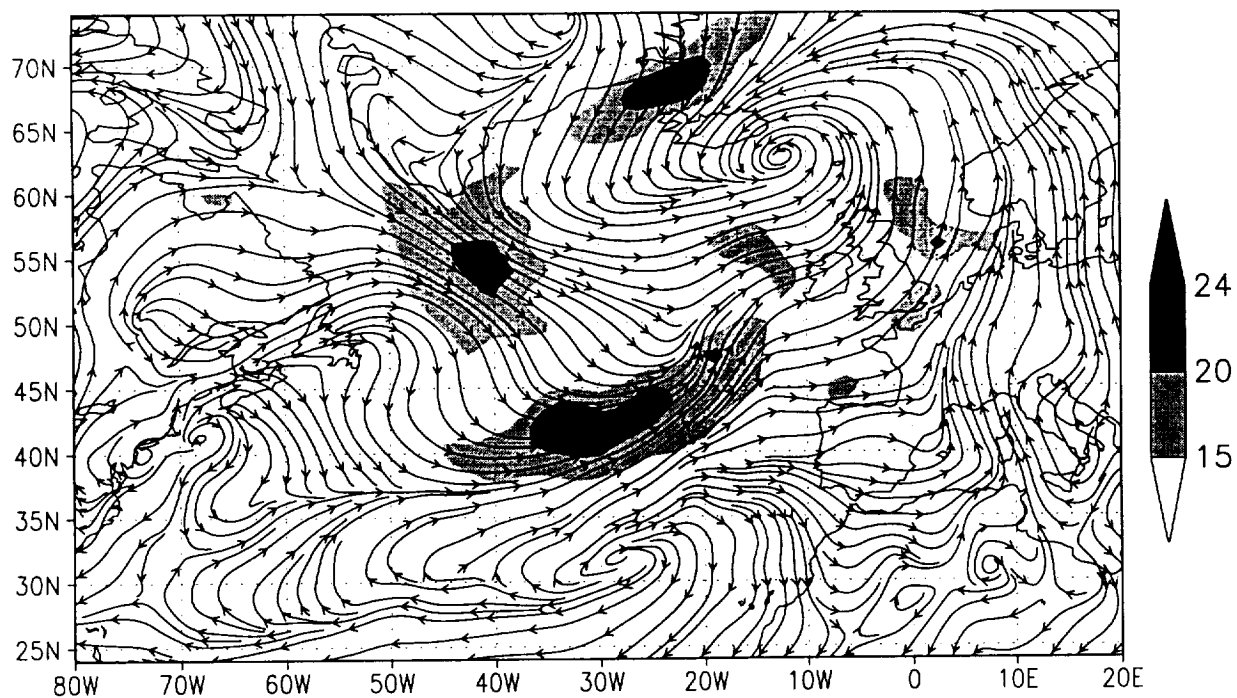Figure 1. Surface winds (m s⁻¹) over the North Atlantic and Europe representative of the winter 1990 scenario; Feb. 1, 1990, 00Z (from ECMWF)
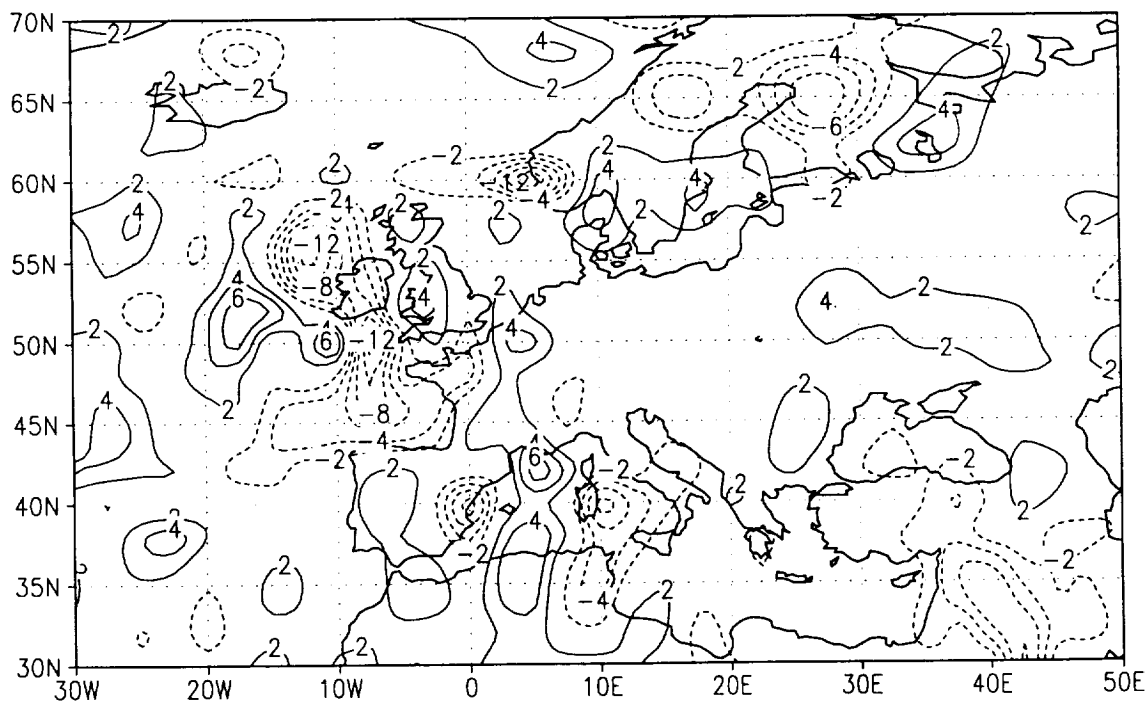

Figure 2. Ascent rates at the 700 mb level (10 Pa s⁻¹); Feb. 1, 1990, 12Z (from ECMWF)
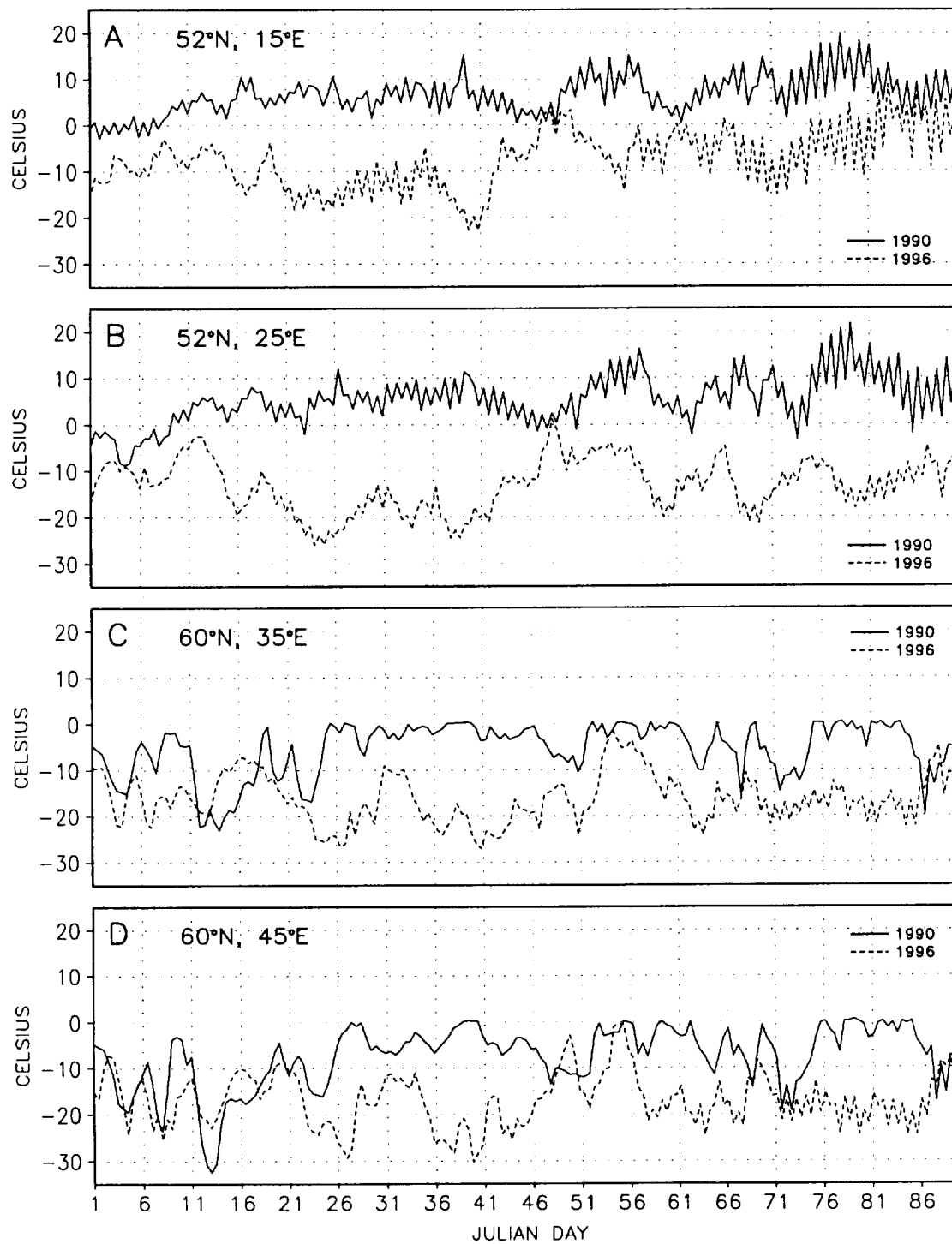
Figure 3. Surface—air temperature at four sites in Europe
vs the Julian date; for 1990 and 1996 (from ECMWF)